# PHILOSOPHICAL TRANSACTIONS.

## I. *On the Ring of Saturn, and the Rotation of the fifth Satellite upon its Axis.* *By* William Herschel, *LL.D. F.R.S.*

Read December 15, 1791.

It is well known to Astronomers that the ring of Saturn becomes alternately enlightened on one of its sides, and that this change of illumination takes place when the planet passes through the node of the ring. This happened in October, 1789, when the southern plane, which had been in the dark for about fifteen years, became visible to us: an event to which I have looked forwards with considerable impatience. In the year 1790, the position of the ring was still too oblique to permit me to examine it well enough to form a proper judgment of its appearance, but lately I have been able to view it to greater advantage, with every one of my telescopes.

In a former paper,* where I ventured to hint at a division of the ring of Saturn, it was highly necessary to express that surmise with proper doubts concerning the reality of so won-

* Phil. Trans. Vol. LXXX. page 4.

derful a construction; but my late views of its southern plane, assisted by some conclusions drawn from the discovery of the quick rotation of the ring, have enabled me to speak decisively on this subject. My suspicion of a divided or double ring arose chiefly from the following circumstances.

In the first place, the black belt, during the time of about ten years that I observed it, on the northern plane, was subject to no kind of change; but remained always, permanently, of the same breadth and colour. With regard to its breadth, it is true that I could only judge of that part of it which goes across the body of the planet, by the rules of perspective, which made me suppose it to be as broad there as it was on the two sides; yet now, as we know that the ring revolves in about ten hours and a half, it is very certain, that the apparently narrow part, across the body, and that which was hidden behind the planet, in the course of an evening, when I have been observing Saturn for many hours together, must have been exposed to view in their full breadth, upon the sides of the ring; and that, if there had been any difference, I must have perceived it; especially as I was continually on the look out for such phænomena, by way of ascertaining, if possible, the rotation of the ring.*

In the next place, the colour of this dark belt was also uniformly the same, whenever I observed it under equally favourable circumstances; and being so well defined on both its

* When I say that the black division was always of the same breadth, I do not mean to exclude very small variations, not only of the breadth of the black mark, but of the ring itself, which I have occasionally observed, and which it may be necessary, hereafter, to communicate at full length; but these, almost imperceptible, differences might arise from causes that are foreign to our present purpose.

borders, and, in every part of the revolving ring, presenting us with the same view of colour, breadth, and sharpness of its outlines, no kind of hypothesis but a division of the ring, through which the open heavens may be seen, will answer the conditions of this phænomenon. It remained therefore only to ascertain, whether the southern plane would present us with the same aspect. And since I have lately had a great number of fine views of the ring of Saturn, I shall here deliver as many of the observations as will be sufficient to throw light enough on the subject, to enable us to decide the question, whether this ring be double or single?

## *Observations on the Ring of Saturn.*

Sept. 7, 1790. 20-feet reflector. No dark division can as yet be seen upon the ring of Saturn; but it is hardly open enough to expect it to be visible.

Aug. 5, 1791. 20-feet reflector. The black list, on this side of the ring of Saturn, is exactly in the same relative place where I saw it on the northern plane.

Sept. 25, 1791. 20-feet reflector. The black division goes all around the ring, as far as I can trace it, exactly in the same place where I used to see it on the north side.

Oct. 13, 1791. 10-feet reflector. The black division upon the southern plane of Saturn's ring, is in the same place, of the same breadth, and at the same distance from the outer edge, that I have always seen it on the northern plane. With a power of 400, I see it very distinctly; it is of the same kind of colour as the space between the ring and the body, but not so dark.

Oct. 24, 1791. 7-feet reflector. With a new, machine-

polished, most excellent speculum, I see that the division on the ring of Saturn, and the open spaces between the ring and the body, are equally dark, and of the same colour with the heavens about the planet.

20-feet reflector. The black division upon the ring is as dark as the heavens. It is equally broad on both sides of the ring. I see it very steadily, and can trace it a good way towards Saturn; both on the part of the ring which is turned towards us, and on that which lies the other way. I trace it as far as the place where a line, perpendicular to the direction of the ring, would touch the inside of the ring, or the outside of the open space between the ring and the body of the planet.

40-feet reflector. I see the division on the ring of Saturn of the same colour as the surrounding heavens. It is of an equal breadth on both sides, and I can trace it a great way towards the body of Saturn.

20-feet reflector. With a power of 600, I can trace the division very nearly as far as the place, where a perpendicular to the direction of the ring, would divide the open space between the planet and the ring, into two equal parts.

From these observations, added to what has been given in some former papers, I think myself authorized now to say, that the planet Saturn has two concentric rings, of unequal dimensions and breadth, situated in one plane, which is probably not much inclined to the equator of the planet. These rings are at a considerable distance from each other, the smallest being much less in diameter at the outside, than the largest is at the inside.

The dimension of the two rings and the intermediate space are nearly in the following proportion to each other.

| | |
|---|---|
| Inside diameter of the smallest ring | 5900 parts. |
| Outside diameter - - - | 7510 |
| Inside diameter of the largest ring | 7740 |
| Outside diameter - - - | 8300 |
| Breadth of the inner ring - | 805 |
| Breadth of the outer ring - - | 280 |
| Breadth of the vacant space - | 115 |

Admitting, with M. DE LA LANDE, that the breadth of the whole ring, as formerly supposed to consist of one entire mass, is near one third of the diameter of Saturn, it follows that the vacant space between the two rings, according to the above statement, amounts to near 2513 miles.

In giving these proportions, which are merely taken from very accurate representations of the phænomena that offered themselves, I do not mean to be scrupulously exact, but reserve a greater accuracy for a future opportunity; when a micrometer, which I have lately applied to the 40-feet telescope, will assist me to have recourse to proper measures.

It may be remarked, that this opening in the ring must be of considerable service to the planet, in reducing the space that is eclipsed by the shadow of the ring to a much smaller compass; both on account of the direct light it lets through, and because there will be a strong reverberation of the rays of the sun between the two opposite edges. Moreover, if these rings should be surrounded by some atmosphere, which is highly probable, the refractions that will take place upon the edges will still contribute to lessen the darkness which the shadow of an undivided ring would have occasioned.

As we have now admitted Saturn to have two rings entirely detached from each other, so as plainly to permit us to

see the open heavens through the vacancy between them; and as in my former paper I have given the revolution of the ring, which was then supposed to be all in one united mass, it will be necessary to examine, whether both rings partake in the same revolution, or to which the period which has been assigned belongs?

To decide this point, we must recur to the observations of the spots by which the rotation of the ring was determined. The spot called $\alpha$,* for instance, which has been observed to revolve with great regularity through upwards of 300 periods, between the 28th of July and the 24th of December, 1789, was certainly situated pretty near the outer edge. The spot $\beta$, as may be gathered from the observation of the 16th of September, and 25th of December, was most likely on the very edge itself; nor could the spot $\delta$ be far from it. This, without considering the situation of $\gamma$ and $\varepsilon$, is quite sufficient to determine us to assign the period we have given to belong to the large, thin and narrow, outward ring.

The spots $\gamma$ and $\varepsilon$ were probably at some distance from the outward edge of the outer ring; but this distance might possibly not exceed that of the inside edge of the same ring. We may however admit them to have adhered to the inner ring, whose rotation is perhaps not very different from that of the outer one; or we may examine whether these two spots may not perhaps agree to some other supposed revolution of the inner ring; but then the observations that are given of them will hardly be sufficient for establishing the time of that ring's rotation with accuracy, though they undoubtedly must amount to a proof that it also revolves with great volocity on its axis.

* See Phil. Trans. Vol. LXXX. page 481.

That there should be a small difference in the periods of the rotation of the two rings, is highly probable from their different dimensions; and now, that the rotation is known, the division of it into two parts seems to be a very natural consequence of its construction. For, when the extreme thinness is taken into consideration, we find by KEPLER's law, of the periods of revolving bodies placed at different distances, that it would be very wonderful for so thin, and so broad a plane, to have adhesion enough to keep together; and that consequently this ring in its divided state, supposing the rotation of the parts to favour the construction, is more permanent than it would be otherwise. This however is only mentioned as a collateral circumstance, and by no means intended either as a proof of the division, or the different rotation of the two parts of the ring. For, notwithstanding we cannot but set the highest value upon the excellent theories that have been lately delivered in the Memoirs of a learned Society, of which I also have the honour to be a member, we must refer entirely to observation for the necessary data on which to found our subsequent computations.

The memoir to which I allude * refers to observations of many divisions of the ring of Saturn. This must lead us to consider the question, whether the construction of this ring is of a nature so as permanently to remain in its present state? or whether it be liable to continual and frequent changes, in such a manner as in the course of not many years, to be seen subdivided into narrow slips, and then again as united into one or two circular planes only? Now, without entering into a discussion, the mind seems to revolt, even at first sight,

* See *Histoire de l'Académie Royale des Sciences de Paris*, 1787, page 249.

against an idea of the chaotic state in which so large a mass as the ring of Saturn must needs be, if phænomena like these can be admitted. Nor ought we to indulge a suspicion of this being a reality, unless repeated and well-confirmed observations had proved, beyond a doubt, that this ring was actually in so fluctuating a condition. Let us therefore examine what facts we have to guide us in this inquiry.

After looking over all my observations upon Saturn, since the year 1774 to the present time, I can find only four where any other black division upon the ring is mentioned than the one which I have constantly observed, and from which I have deduced the actual division of the ring into two very unequal portions. These observations are as follows.

June 19, 1780. $10^h$ 15′ mean time. With a new 7-feet speculum, having an aperture of 6,4 inches, with also a much improved small speculum, and a power of about 200. I see a second black list upon the ring of Saturn, close to the inner side, on the preceding arm of the ring. See figure 1. Tab. I.

June 20, 1780. $10^h$ 10′. I see the same double list on the preceding side of the ring.

June 21, 1780. $10^h$ 1′. Small 20-feet, Newtonian reflector, power 200. I see the second black list on Saturn's ring. It is closer to the inside than the other is to the outside; but it is only visible on the preceding side of the ring. See figure 2.

June 26, 1780. $9^h$ 34′. Small 20-feet, Newtonian reflector; aperture confined to 7 inches. The 2d black list, on the preceding side of the ring of Saturn, is visible.

June 29, 1780. $10^h$ 19′. Saturn's belts are very clear. I see but one black list upon the ring. The shadow of the planet

is visible upon the side of the ring, as well as upon the small northern part that projects beyond the planet. See fig. 3.

Nov. 21, 1791. $0^h$ 28′ sid. time. 40-feet reflector, power 370. There is no other black division visible upon the ring of Saturn but the one near the outer edge.

It must be confessed that Saturn was in the very best situation for viewing the plane of the ring, when the first four observations were made; and that consequently they may be looked upon as a strong evidence for another division. But hitherto I have set them aside as wanting more confirmation, not only because I could never perceive the same dark line on the following side of the ring as well as on the preceding side; nor since I could not find it on the 29th of June, 1780, as we have seen above; but chiefly, because I have not been able, with any of my best instruments, to see it again at all. We also find by the observation of the 21st of November, 1791, which has been added, that the southern plane, as yet, presents us with no other division than the capital one, which I have observed these thirteen years, on both sides of the ring. However, if the opening should be very narrow, and the rings eccentric, it is possible that a dark line might by this means become visible on one side only. Moreover, these objects may be so minute, that no other time than when the plane of the ring is exposed as much as it can possibly be, will do to ascertain such phænomena. This will happen again about the year 1796, when we may hope to have a satisfactory view of it, with our large instruments.

It remains now to consider the observations that have been made by M. Cassini, Mr. Short, and Mr. Hadley.

Without being in possession of the original observations of

M. CASSINI, I cannot decide whether the black list which he saw was the same which I have observed. M. DE LA LANDE says (*Ast.* Vol. III. page 441.) that CASSINI saw it divided by a small black line into two *equal* parts. M. DE LA PLACE (*Mémoire sur la Théorie de l'Anneau de Saturne*) mentions that CASSINI saw the breadth of the ring divided into two parts *almost* equal. It should seem from this, that M. CASSINI was not particularly attentive to the proportions of the division; in which case his observations and mine will agree perfectly well; but if he has any where expressly mentioned, that the ring was divided into *equal* parts, so that we may be certain he was particularly attentive to that circumstance, it will follow evidently that the ring, since his time, has undergone a very capital change in its construction.

Mr. SHORT assured M. DE LA LANDE, that he had seen many divisions upon the ring, with his telescope of 12-feet. A thing of such consequence, and so new, ought certainly to have been given in a more satisfactory and circumstantial way than only by communicating it, from memory, in conversation, to another person. Besides, it is well known that many telescopes will give double and treble images, and that especially those which have large apertures are subject to tremors, which multiply small lines. For these reasons, we can hardly take into account observations that seem not to be sufficiently established. What has been said is, however, by no means intended to undervalue Mr. SHORT's observations; and this, I hope, will be evident, when it is remembered how scrupulously I have just before set aside four of my own, because I looked upon them as not sufficiently confirmed.

Mr. HADLEY's observation of the division of the ring, with a

$5\frac{1}{2}$-feet Newtonian reflector, which was certainly a very excellent instrument, agrees perfectly well with mine.

From what has been said, it does not appear to me that there is a sufficient ground for admitting the ring of Saturn to be of a very changeable nature, and I guess that its phænomena will hereafter be so fully explained, as to reconcile all observations. In the mean while, we must withhold a final judgment of its construction, till we can have more observations. Its division, however, into two very unequal parts, can admit of no doubt; and the following are measures taken of the diameter of the largest or outward ring.

Oct. 7, 1791. *Correction of the 20-feet clock* — 2′ 16″,5.

Measures of the ring of Saturn with the 20-feet reflector.

| | | |
|---|---|---|
| $0^h$ 37′ | 1st measure | 54″,115 |
| | 2d ——— | 52 ,537 |
| | 3d ——— | 52 ,875 |
| | 4th——— | 54 ,679 |
| | 5th——— | 52 ,903 |
| | 6th——— | 53 ,044 |
| | 7th——— | 53 ,411 |

53″,366 mean of the seven measures.

Proper allowance was made for the wires being tangents to the outside of the ring.

When this measure is reduced to what it would be at the mean distance of Saturn from the earth, we have 46″,832.

Oct. 24, 1791. *Correction of the 40-feet clock* + 25″,4.

Measure of the ring of Saturn with the 40-feet reflector. Power 370.

| | | |
|---|---|---|
| $1^h\ 3'$ | 1st measure | $53'',914$ |
| | 2d ——— | $53\ ,260$ |

$53'',587$ mean of the two measures.

Reduced to the mean distance of Saturn, the measure is $47'',241$.

Nov. 21, 1791. *Correction of the* 40*-feet clock* — $7'',8$.

Another measure of the ring of Saturn with the 40-feet reflector. Power 370.

| | | |
|---|---|---|
| $0^h\ 48'$ | 1st measure | $50'',627$ |
| | 2d ——— | $50\ ,042$ |
| | 3d ——— | $50\ ,808$ |

$50'',492$ mean of the three measures.

Reduced to the mean distance of Saturn the measure is $45'',803$.

| | |
|---|---|
| Oct. 24 | $47'',241$ |
| Nov. 21 | $45\ ,803$ |
| | $46'',522$ mean of the measures with the 40-feet reflector. |
| 40-feet | $46'',522$ |
| 20-feet | $46\ ,832$ |
| | $46'',677$ mean of all the measures. |

By way of forming more easily a comparative idea of the stupendous size of this ring of Saturn, I have calculated the proportion it bears to the earth, and find that its diameter is to that of the latter as 25,8914 to 1; and that consequently,

when seen at the mean distance of the sun, it will subtend an angle of 7′ 25″,332.

From the above proportions we also compute that this ring must be upwards of 204883 miles in diameter.*

*On the Rotation of the fifth Satellite of Saturn, on its Axis.*

In my frequent observations of the Saturnian system, I remarked, that the 5th satellite is subject to a change of brightness. This having been noticed before by other observers, I did not at first pay so much attention to it as I soon afterwards found this circumstance deserved. When I saw this satellite always assume the same brightness in the same part of its orbit, and perceived that its change was regular and periodical, it occurred to me very naturally, that the cause of this phænomenon could be no other than a rotation upon its axis. It became necessary therefore to find out a method to determine the time of this rotation.

In order to investigate this, I pursued the satellite with great attention, and marked all its changes of apparent brightness. The result of many observations is as follows. The light of the satellite is in full splendour during the time it runs through that part of its orbit which is between 68 and 129 degrees past the inferior conjunction. In passing through this arch it does not fall above one magnitude short of the brightness of the 4th satellite. On the contrary, from about 7 de-

* In this calculation I have used for the earth's diameter the sum of the longer and shorter semi-axes which are given in Mr. DALBY's Paper, published in the last volume of the Philosophical Transactions. If we compute the vacant space between the two rings immediately from the above dimensions of the outward ring, we shall have 2839 miles; and this will certainly be more accurate than the result which has been drawn from the proportion of the breadth of the ring to the diameter of Saturn.

grees past the opposition till towards the inferior conjunction, it is not only less bright than the 3d, but hardly, if at all, exceeds the 2d, or even the 1st satellite; provided the latter be then about its greatest elongation, where its light is least impeded by the brightness of the planet. Upon the whole, the alteration seems to amount to what among the fixed stars, and with the naked eye, would be called a change from the 5th to the 2d, and from the 2d to the 5th magnitude.

Having thus observed this satellite, for many of its revolutions round the primary planet, to lose and regain its light regularly, it is evident that the time of its rotation on its axis cannot differ much from that of its revolution round Saturn. I think myself sufficiently authorized to make this conclusion, notwithstanding it may have happened sometimes that the light of the satellite has suffered an occasional change, of short duration, from other causes; for the same reason that we should certainly allow those who first saw the spots in the sun to be in the right to assign the period of its rotation *nearly*, when they perceived that the same spot made several revolutions, notwithstanding that spot might afterwards vanish. But I may go farther, and ascertain upon sufficient grounds, that this satellite turns once upon its axis, exactly in the time it performs one revolution round its primary planet. This degree of accuracy is obtained by taking in the observations of M. CASSINI, which are related in the *Mémoires de l'Académie des Sciences*, 1705, page 121; where we find it mentioned, that "the 5th satellite of Saturn disappears regularly for about one "half of its revolution, when it is to the east of Saturn." The same memoir contains also a conjecture of this satellite's rotation upon its axis; but this surmise is contradicted as prema-

ture, in 1707, page 96; where we find the following paragraph. " M. CASSINI gives an example of the danger there is " in these sort of determinations, that are made too hastily. " The 5th satellite of Saturn, of which we have said, in the " History of 1705, page 121, that it grew invisible, in the " eastern half of the circle it describes about Saturn, began, " in the month of Sept. 1705, to be there visible, as well as in " the western half, where it always was so. Hence the con- " jectures which we have related cease to be well founded."

Now, without determining whether the satellite, from some cause or other, ceased to change its brightness, or whether its phænomena were not sufficiently followed to come to a proper conclusion, I think that with the assistance of observations at so great a distance of time as those of M. CASSINI, I may sufficiently establish the period of this satellite's rotation. For since I have traced the regular, and periodical change of light, through more than ten revolutions, and find them, in all appearance, to be contemporary with its return about Saturn, it leads us directly to a strong presumption that its rotation upon its axis, like that of our moon, strictly coincides with its revolution round its primary planet; and the observations of M. CASSINI completely confirm this conclusion. For, had he seen the satellite brightest in any other part of its orbit, our observations would not have agreed together; but since the year 1705, the satellite has made about 397 revolutions; and yet the phænomena described by CASSINI answer now as exactly to my own observations, as the spots in our moon, viewed in CASSINI's time, answer to those we now observe.

If it should be objected, that the 5th satellite of Saturn has not been continually observed, and that consequently these ap-

pearances might either not happen at all, or fall upon different places in its orbit; I answer, that a period of more than ten revolutions, which I have included, is already a strong argument that no such change has taken place; for if the satellite had but made a single rotation upon its axis more or less than it has made revolutions round Saturn, the change must amount to nearly one degree *per* revolution; that is, to about ten degrees during the time of my taking notice of it; which is a quantity I think I might have perceived. However, to remove all doubt, we have some valuable observations of M. BERNARD, who in the year 1787, also found the 5th satellite of Saturn subject to the same change of light that M. CASSINI had observed.* Now, by joining those to mine, we have a short period of near 20 revolutions that agree together, so as to preclude all doubt of any intermediate change; and therefore we cannot be liable to err, when we extend this period to all the 397 revolutions since CASSINI's time, and by that means ascertain that the 5th satellite of Saturn turns upon its axis, once in 79 days, 7 hours, and 47 minutes.

I cannot help reflecting, with some pleasure, on the discovery of an analogy, which shews that a certain, uniform plan is carried on among the secondaries of our solar system; and we may conjecture, that probably most of the moons of all the planets are governed by the same law; especially if it be founded on such a construction of the figure of the secondaries, as makes them more ponderous towards their primary planets. For, if even the 5th satellite of Saturn, which is at so great a distance from its planet, is affected by such a law, of course the other satellites are not very likely to have escaped its influence.

* See *Mémoires de l'Académie*, 1786, page 378.

From the considerable change in the brightness of the 5th satellite of Saturn, we may be certain that some part of its surface, and this by far the largest, reflects much less light than the rest; and, from the points of its orbit in which it appears brightest to us, we conclude that neither the darkest nor brightest side of the satellite is turned towards the planet, but partly one and partly the other; though probably rather less of the bright side.

The great regularity of this change of brightness seems to point out another resemblance of this satellite with our moon. It is well known that we see the spots of the moon pretty nearly of the same brightness, so as not to be overcast in a very strong degree by dense clouds to disfigure them, and therefore have great reason to surmise that her atmosphere is extremely rare; which indeed we also know from other principles: In like manner, on account of the uninterrupted changes in the brightness of the 5th satellite of Saturn, we may suppose that it also partakes of a similar fate with respect to its atmosphere, which is probably as rare as that of our moon.

## *On the Distance of the fifth Satellite.*

The distance of the 5th satellite from Saturn is allowed to be the most proper for obtaining a true measure of the quantity of matter contained in the planet; for which reason I have taken many measures of it with the 20-feet reflector. I give them at full length, that the validity of them may appear in its proper light.

Sept. 25, 1791. *Correction of the clock* — 2′ 19″,5 *for midnight.*

Distance of the 5th satellite of Saturn from the centre of the

planet; measured with the 20-feet reflector, and a magnifying power of 157.

| | | | |
|---|---|---|---|
| $23^h$ | $4'$ | 1st measure | $8'\ 55'',684$ |
| 23 | 19 | 2d ——— | 8 53 ,175 |
| 23 | 33 | 3d ——— | 8 59 ,179 |
| 23 | 47 | 4th ——— | 8 52 ,123 |
| 23 | 55 | 5th ——— | 8 56 ,361 |
| 0 | 2 | 6th ——— | 8 55 ,797 |

$8'\ 55'',5$ mean of the six measures.

Sept. 26, 1791. *Correction of the clock* — $2'\ 19'',8$.

| | | | |
|---|---|---|---|
| $23^h$ | $15'$ | 1st measure | $9'\ 3'',745$ |
| 23 | 25 | 2d ——— | 9 2 ,758 |
| 23 | 31 | 3d ——— | 9 7 ,014 |
| 23 | 38 | 4th ——— | 9 6 ,592 |
| 23 | 42 | 5th ——— | 9 8 ,001 |
| 23 | 45 | 6th ——— | 9 6 ,479 |

$9'\ 5'',8$ mean of the six measures.

Sept. 27, 1791. *Correction of the clock* — $2'\ 20'',0$.

| | | | |
|---|---|---|---|
| $22^h$ | $53'$ | 1st measure | $9'\ 20'',656$ |
| 22 | 57 | 2d ——— | 9 20 ,359 |
| 23 | 1 | 3d ——— | 9 20 ,149 |
| 23 | 5 | 4th ——— | 9 20 ,641 |
| 23 | 11 | 5th ——— | 9 20 ,064 |
| 23 | 16 | 6th ——— | 9 20 ,840 |

$9'\ 20'',5$ mean of the six measures.

Sept. 28, 1791. *Correction of the clock* — 2′ 20″,2.

| | | | |
|---|---|---|---|
| 21h 38′ | 1st measure | 9′ 27″,759 | |
| 21 44 | 2d ——— | 9 29 | ,957 |
| 21 46 | 3d ——— | 9 27 | ,815 |
| 21 50 | 4th ——— | 9 28 | ,238 |
| 21 53 | 5th ——— | 9 28 | ,970 |
| 21 58 | 6th ——— | 9 27 | ,420 |

9′ 28″,4 mean of the six measures.

Sept. 29, 1791. *Correction of the clock* — 2′ 20″,4.

| | | | |
|---|---|---|---|
| 0h 17′ | 1st measure | 9′ 37″,060 | |
| 0 22 | 2d ——— | 9 36 | ,552 |
| 0 26 | 3d ——— | 9 36 | ,270 |
| 0 29 | 4th ——— | 9 36 | ,862 |
| 0 33 | 5th ——— | 9 37 | ,765 |
| 0 36 | 6th ——— | 9 37 | ,060 |

9′ 36″,9 mean of the six measures.

Sept. 30, 1791. *Correction of the clock* — 2′ 20″,6.

| | | | |
|---|---|---|---|
| 20h 25′ | 1st measure | 9′ 39″,258 | |
| 20 29 | 2d ——— | 9 38 | ,441 |
| 20 34 | 3d ——— | 9 37 | ,596 |
| 20 38 | 4th ——— | 9 37 | ,032 |
| 20 40 | 5th ——— | 9 40 | ,949 |
| 20 42 | 6th ——— | 9 37 | ,793 |

9′ 38″,5 mean of the six measures.

Supposing the satellite now to be not far from its greatest elongation, I measured the declination between the centre of Saturn, and the 5th satellite; causing one to pass along one wire, while the other followed upon the other wire.

| | | | |
|---|---|---|---|
| $22^h\ 32'$ | 1st | measure | $1'\ 41'',889$ |
| 22 47 | 2d | ——— | 1 45 ,609 |

$1'\ 43'',749$ mean of the two measures.

Not being satisfied with the considerable disagreement, I took another measure with the utmost precaution and care; as the apparent curvature of the wires at so great a distance, required more than common attention.

$0^h\ 52'$ very exact. $1'\ 43'',354$

Mean between this and the former mean, $1'\ 43'',55$ south of the parallel of Saturn.

The satellite not being perhaps arrived at its greatest elongation, I took six other measures of its distance.

| | | | |
|---|---|---|---|
| $1^h\ 5'$ | 1st | measure | $9'\ 41'',907$ |
| 1 11 | 2d | ——— | 9 38 ,723 |
| 1 14 | 3d | ——— | 9 38 ,159 |
| 1 18 | 4th | ——— | 9 41 ,203 |
| 1 23 | 5th | ——— | 9 40 ,385 |
| 1 26 | 6th | ——— | 9 41 ,935 |

$9'\ 40',4$ mean of the six measures.

In the last six measures of the 5th satellite, I used a method a very little different from that which I employed before, and which is probably more accurate. I used to observe, when the

two wires were nearly brought to their proper distance, the moment of intersection of the satellite; and the instant it was hid behind the wire, cast my eye on Saturn, which should be bisected when the measure is justly taken. But this change of attention cannot be made without some very small loss of time. To correct this defect I took alternately the bisection of Saturn, and cast my eye upon the satellite; and the bisection of the satellite, casting the eye upon Saturn. As the latter way gives the interval too small, the former gives it too large, and between both the true measure may be obtained. I do not, however, suppose, that the error of the former method can amount to so much as a single second of space; as, knowing the loss of time, I always used the utmost precaution; and repeated the examination of a measure perhaps 20 times before I let it pass.

Oct. 1, 1791. *Correction of the clock* — 2′ 20″,0.

| | | | |
|---|---|---|---|
| $22^h\ 25'$ | 1st | measure | $9'\ 43'',767$ |
| 22 27 | 2d | ——— | 9 44 ,444 |
| 22 30 | 3d | ——— | 9 43 ,007 |
| 22 32 | 4th | ——— | 9 42 ,499 |
| 22 34 | 5th | ——— | 9 40 ,554 |
| 22 36 | 6th | ——— | 9 43 ,965 |

$9'\ 43'',0$ mean of the six measures.

It grew cloudy, so that no measures later in the night could be obtained; nor could I get another sight of Saturn till October the 7th, when the satellite was far advanced in its orbit, on its return towards the planet.

Supposing the satellite to have been very nearly at its

greatest elongation, when the last six measures were taken, I have reduced them to the mean distance of Saturn, where they give 8′ 31″,97.

I forbear making deductions from this result, with respect to the quantity of matter contained in the planet, as, possibly, the orbit of the satellite may be considerably elliptical; in which case measures taken in opposite parts of that orbit will be required, before we can make a strict application of the laws of centripetal forces.

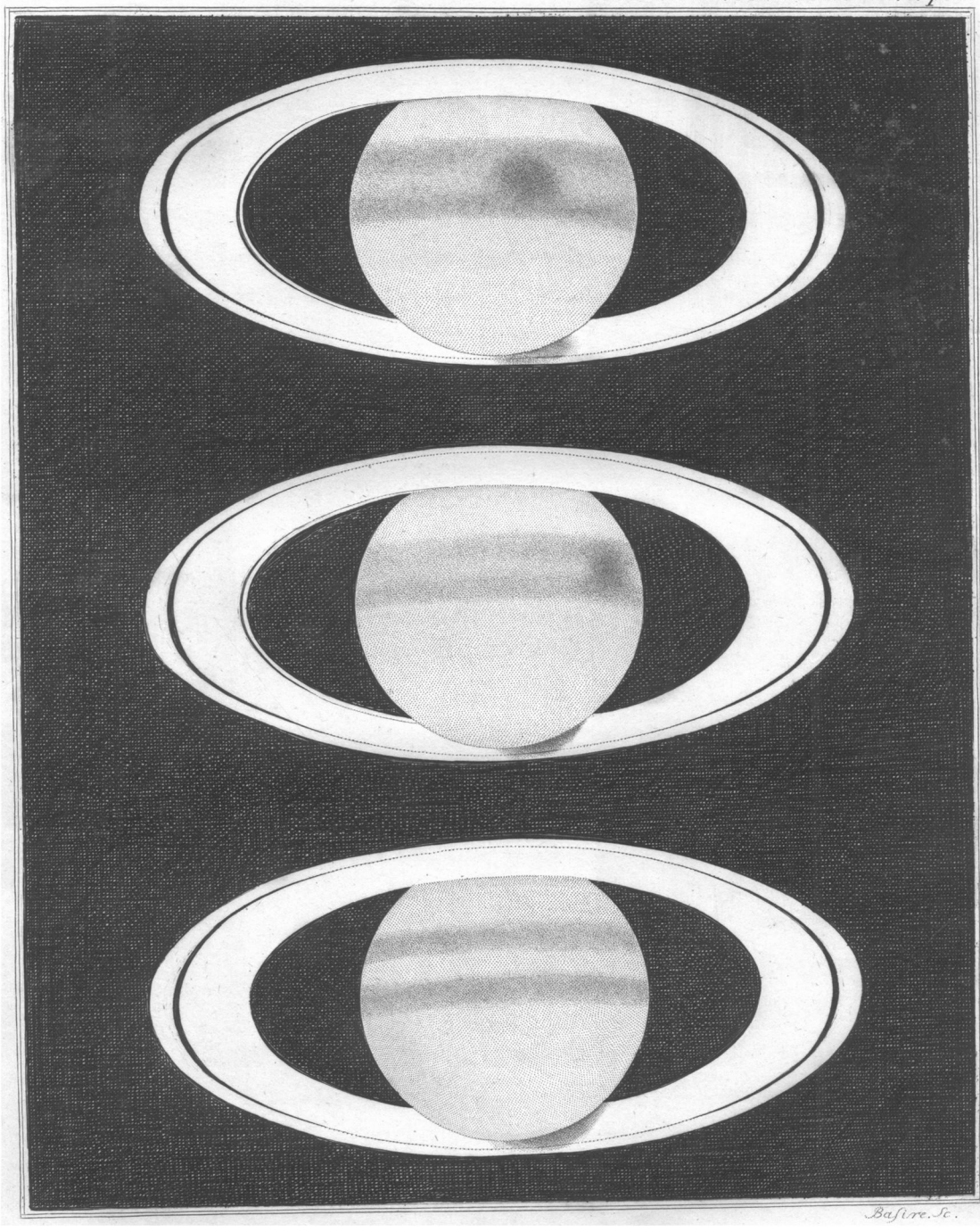

*Fig* 1

*Fig* 2

*Fig* 3

*Basire. Sc.*